Available online at www.sciencedirect.com

ScienceDirect

Procedia
Social and Behavioral Sciences

Procedia - Social and Behavioral Sciences 96 (2013) 473 – 479

13th COTA International Conference of Transportation Professionals (CICTP 2013)

A Review of Yellow Dilemma Problem and a Dynamic Speed Guidance System Design Based on CVIS

Mozan Li[a], Linan Zhang[a], Xiaoguang Yang[a] *

[a] *School of Transportation Engineering and Key Laboratory of Road and Traffic Engineering, Ministry of Education, Tongji University,4800 Cao'an Road Jiading District, Shanghai 201804, China*

Abstract

The existence of dilemma zone is the main reason for accidents and violation of traffic laws near signal intersections. Firstly, the concepts of the yellow interval dilemma and the reasons why there exists the yellow interval dilemma are introduced in this paper. Then, the existing solutions of the yellow dilemma problem are introduced and their drawbacks are also analyzed. The previous researches are mainly based on simulation and there is not much study on the actual system design. The design of a Dynamic Speed Guidance System under CVIS is developed, which is of vital significance in reality.

Keywords: traffic engineering;yellow dilemma; traffic safety; CVIS;system design

0. Introduction

Intersections have always been the main place for accidents, and the existence of yellow dilemma problem is the main reason for accidents and violation of traffic laws near signal intersections. So the yellow interval dilemma problem has been the focus of people's attention, especially since the new traffic rule took place in China in 1st January which impose heavier penalty on behaviours of rushing yellow light. With the development of CVIS(Cooperative Vehicle Infrastructure System), many CVIS-based solutions has been proposed to solve the dilemma problem, but the previous researches were mainly based on simulation, therefore on the basis of the summary and analysis of the previous studies, the design of a Dynamic Speed Guidance System Under CVIS is developed in this paper.

* Mozan Li. Tel.: +86-188-1784-6278; fax: +86-021-6958-3712.
E-mail address: 3201080102@163.com

doi:10.1016/j.sbspro.2013.08.055

1. The yellow interval dilemma

1.1. Basic concepts of the yellow interval dilemma

When the yellow indication commences and the driver is at a distance X from the intersection, he has two choices: either to bring the vehicle to a full stop before the stopping line or to clear the clearing line before the signal turns red (Chiu Liu, Robert Herman, 1996). The yellow interval dilemma means a situation in which the vehicle can neither stop before the stopping line nor clear the clearing line before the signal turns red. When a vehicle is in a dilemma zone, no matter which the choice is, it must result in either sudden braking or rushing the red light (Denos Gazis, Robert Herman, 1960).

As is shown in Figure 1, the grey area indicates the range that the vehicle could not clear the clearing line during the yellow light, and the blue one indicates the range that the vehicle could not stop before the stop line, while the red one indicates the yellow interval dilemma zone. X is the distance between the vehicle and the intersection; X_t and X_s mean the critical clearing distance and the critical stopping distance respectively.

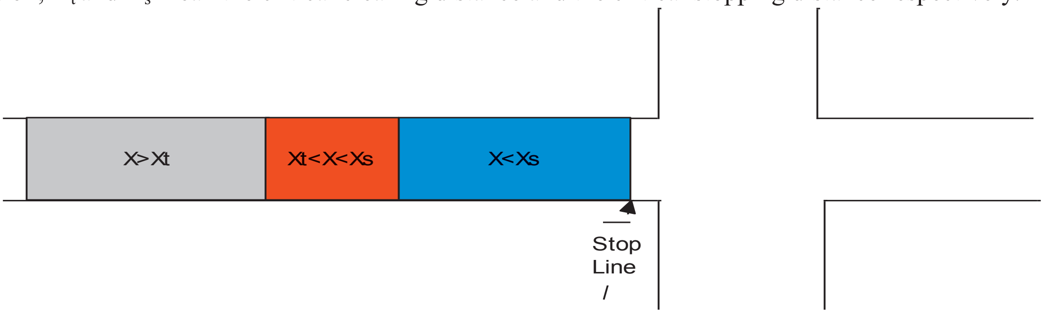

Fig. 1. Analysis of the yellow interval dilemma

If a vehicle can clear the stopping line during the yellow light period, then the following formula must be satisfied:

$$X < V \times A + \mathrm{a}\left(A - \mathrm{t_r}\right)^2 / 2 \tag{1}$$

But in a practical situation a driver tends to drive in a high speed, so X_t can be denoted by the following equation:

$$X_t = V_{\lim} \times A \tag{2}$$

In the above formulas, V is the velocity when the vehicle runs into the intersection area, A is the yellow light period, t_r is the driver perception-reaction time, a is the acceleration of the vehicle, and $V_{\lim}$ is the speed limit of the intersection.

On the other hand, if a vehicle can stop during the yellow period, then the following formula must be satisfied:

$$X > V \times t_r + V^2 / \left(2d\right) \tag{3}$$

where d is the deceleration of the vehicle. Provided that $V = V_{\lim}$ and $d = d_c$ which means the highest deceleration in a comfortable way, then the following equation is obtained:

$$X_S = V_{\lim} \times t_r + \frac{V_{\lim}^2}{2d_C} \tag{4}$$

The yellow interval dilemma will exist, when $X_t<X_s$, and $X_t<X<X_s$. Therefore, in theory, if the dilemma zone is to be eliminated, $X_t = X_s$ must be satisfied. Then equation (5) is obtained:

$$A_O = \mathrm{t}_r + V_{\lim} / \left(2d_C\right) \tag{5}$$

where Ao is the optimal yellow period which can eliminate the dilemma zone in theory.

1.2. Analysis of causes of the dilemma problem in reality

From the analysis in section 1.1, it can be obtained that if $A = A_o$, then the dilemma zone can be eliminated in theory. But due to factors like the unsuitable yellow signal period, individual differences among drivers and the impact of bad weather and so on, the dilemma problem is still a common issue in real life.

(1) The unsuitable signal period

It is known from equation (5) that Ao differs according to different speed limits of intersections. The higher V_{lim}, the longer A_o should be. But in China, in most intersections the speed limit is set to be 3s, no matter how high V_{lim} is, which is an important reason for the dilemma problem.

(2) The misjudgement of drivers

On sight of yellow light, some drivers may assume that they can cross the intersection before the red lightcommences and so take actions to accelerate; after driving a certain distance, they may think that they couldn't cross the street successfully, then they have to brake immediately, but it is impossible to stop before the stop line.

(3) Individual differences among drivers

Study has shown that a too high or too low speed can both result in the dilemma problem (Chiu Liu, Robert Herman, 1996). For instance, adventurous drivers tend to drive in a speed close to even higher than V_{lim}, resulting in a longer X_s which is higher than X_t; meanwhile, if V is lower than a certain value, the dilemma problem can also be caused, no matter how long the yellow interval.

(4) Bad weather impact

When it rains or snows, especially it is icy on the road, the safe stopping distance will be greatly increased, which is the period of a high accident rate. This makes it more difficult to stop before the stopping line.

2. Existing Solutions and their characteristics

2.1. Static Solutions

2.1.1. Setting yellow light properly

Setting yellow interval at a suitable value can eliminate dilemma problem in a certain range of speed. The optimal yellow interval varies from different speed limit at intersections. It has been shown that if $V_{lim} <= 40$ km/h, A can be set as 3s; while if $V_{lim} > 40\sim70$ km/h, then A can be set as 4s. At the same time, when the speed limit is above 70km/h in road segment, then speed limit at intersections should be transformed to no higher than 70km/h (Keping Li, Peikun Yang, Ying Ni, 2010).

2.1.2. A solution under coordinated control

Studies have shown that volume, distance between intersections ,offset and the interaction effect of distance between intersections and the offset are the most significant factors affecting dilemma problem. Therefore, an optimal coordination of the levels of these factors can improve the safety of the dilemma zone (Xuefeng Chen, Wanjing Ma, 2011).

Static solutions for dilemma problems can remove most dilemma zones for most vehicles. However, there have been some concerns about shortcomings of the above solutions which limited their applications. The main concern is that since the yellow interval is constant under these solutions, so its main drawback is the lack of response to real-time traffic and road conditions. Another concern is its lack of ability to eliminate the impacts of individual differences and misjudgments of drivers. A third concern is the potential negative impact of coordinated control on cross street traffic.

2.2. Dynamic solutions

2.2.1. Actuated signal control strategy

This strategy is based on detectors embedded in the approach of an intersection. These detectors detect whether there are vehicles staying in the dilemma zone when the amber light is about to commence, then strategies will come into operation accordingly, including strategies like extending green light of this phase aiming at cutting down dangerous rate, and extending the green light interval aiming at ensuring safety (Wei Huang, Wanjing Ma, Xiaoguang Yang, 2009; Wei Huang, Xiangdong Jin, Wanjing Ma, 2008; Cunbao Zhang, Chao Chen, Xinping Yan, 2012).

This strategy can response to real-time traffic conditions and can solve the dilemma problem effectively. But it can bring potential negative impact on cross traffic making them falling into dilemma zone; moreover, whether ordinary vehicles have higher priority levels in one approach than cross street traffic is worthy discussing, otherwise inequality may occur.

2.2.2. Speed Guidance Strategy

In recent years, various on-board equipment have been universal (Hao Chu, Xiaoguang Yang, Tong Zhu, Zhuo Wang, 2008), and the technology of cooperated vehicles and infrastructures has been more mature. All these factors make it easier and more realistic to exchange information including location and speed information of vehicles, and traffic light setting information and so on. Therefore, many researchers have proposed the speed guidance strategy under CVIS, and have tested its effectiveness with simulation software. Simulation with Vissim has shown that changing speed of vehicles approaching an intersection in a certain range by analyzing information like the signal light state and the remaining time of this phase as well as speed and location of vehicles, can prevent vehicles being trapped into dilemma zone when the yellow light starts. Its flow chart of the control algorithm is shown in Figure 2.

According to its operating procedure, the speed guidance strategy under CVIS can promptly response to real-time traffic conditions and solve the dilemma problem for most vehicles just as the actuated signal control strategy does; meanwhile, compared to the other strategies mentioned in the previous section, the speed guidance strategy can eliminate dilemma problems caused by different driving behaviors and drivers' misjudgments.

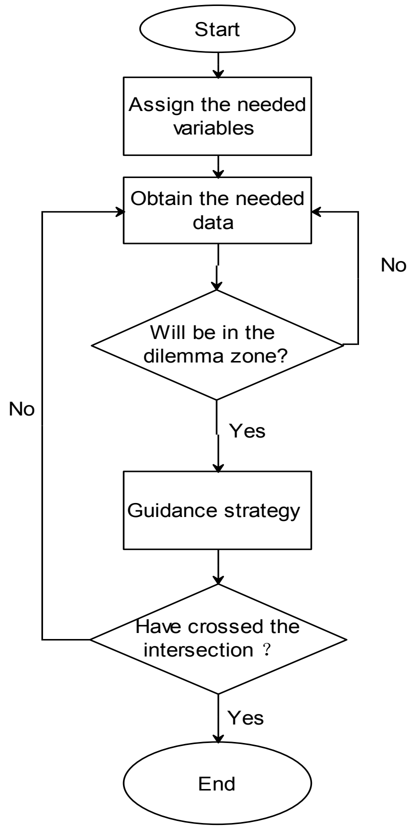

Fig. 2. Flow chart of speed guidance control algorithm

3. A design of a Dynamic Vehicle Speed Guidance System under CVIS

Although CVIS-based speed guidance strategy has been proposed in previous work, most study is based on simulation and is mainly focused on theoretical analysis. Therefore, it is necessary to develop a design of the system framework. In this section, a Dynamic Vehicle Speed Guidance System under CVIS development is developed.

As is shown in Figure 3, the system consists of two components: signal controller, intelligent vehicle with on board unit. These two parts communicate through Denso WSU (Wireless Safety Unit). Denso WSU is a kind of wireless communicative unit which supports WAVE (Wireless Access in Vehicular Environments).

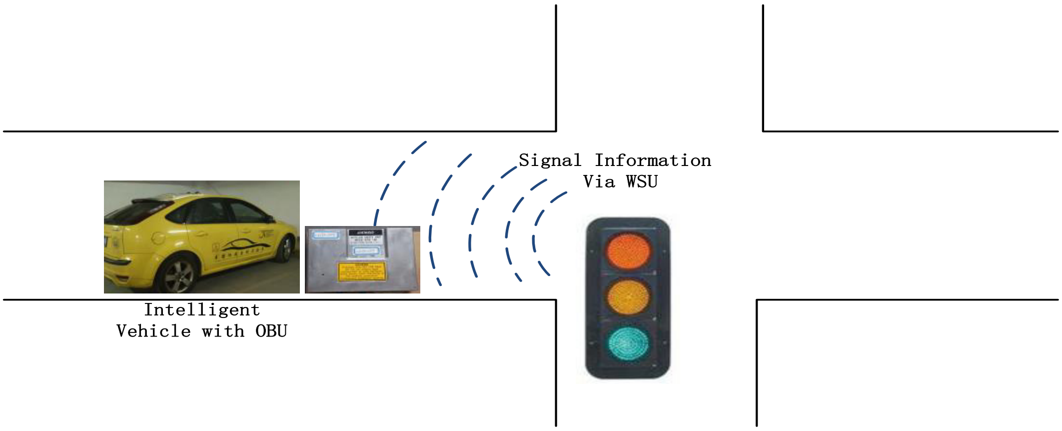

Fig. 3. A dynamic vehicle speed guidance system under CVIS

Figure 4 has shown the more detailed architecture of the on board unit in intelligent vehicles. OBU is composed of three parts: GPS positioning and analyzing unit, Processing center, and display screen with an audio unit.

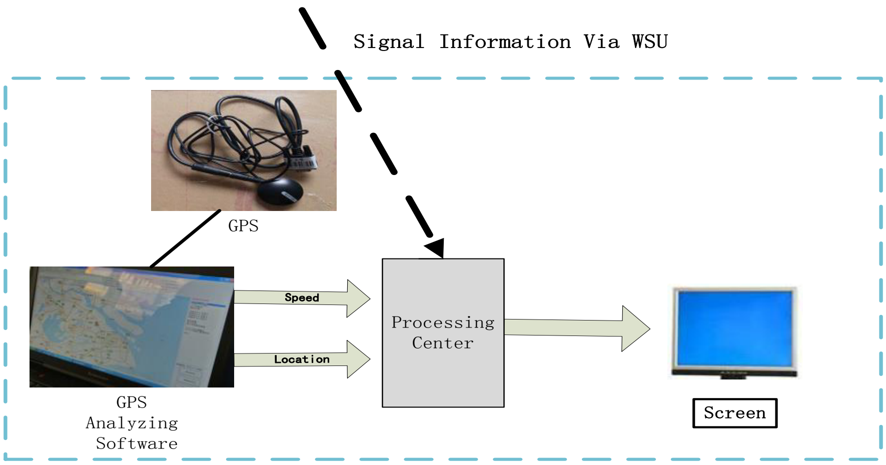

Fig. 4. On board unit of intelligent vehicles

OBU will keep searching signals coming from WSU roadside unit connected with signal controllers. As soon as an intelligent vehicle is in the communication range of WSU, then the processing center will get traffic light information, including the current signal setting strategy, traffic light state and the remaining time of this state, from signal controllers via WSU. Meanwhile, GPS positioning and analyzing unit will convey the speed and the distance from the intersection to the processing center. Then the processing center will generate a speed guidance strategy through the algorithm shown in Figure 2 according to the information it receives; and the result of the guidance will be conveyed to the display screen. Whether to change speed of the vehicle (accelerate or decelerate) or not will be shown on the screen (if the guidance is to suggest the driver changing his speed, then the suggested speed will also be shown on the screen). At the same time, the information shown on the screen will also be heard through the audio unit by drivers.

4. Conclusions

Along with the development of the technology of CVIS, and the increasing application of intelligent on-board unit, CVIS becomes an important tool to ensure the safety of intersections. Therefore, studies on the application

of these technologies on improvement of intersection safety and its operating pattern are crucial. Through the analysis of this paper, conclusions are as follows:

- Proper yellow light interval should be applied according to speed limit at intersections, and coordinated control should be conducted if it is necessary. These methods can eliminate most dilemma problems;
- The technology of CVIS can prevent vehicles being trapped in dilemma zone caused by different driving behaviors, and develops a new direction in solving traffic safety problems, which is the new trend of studies;
- A design of dynamic speed guidance system under CVIS provides practical proof for application of CVIS in real life.

Acknowledgements

This work is supported in part by the Ministry of Science and Technology of the People's Republic of China (2011AA110404) and the National Natural Science Foundation of China (60974093/F030209).

References

Chiu Liu, Robert Herman. A review of the yellow interval dilemma. Transportation Research Part A, 1996,30: 333-348.
Denos Gazis, Robert Herman, Alexei Maradudin. The Problem of the Amber Signal Light in Traffic Flow.Operation Research, 1960,8:112-132.
Keping Li, Peikun Yang, Ying Ni. Amber Interval Design at Urban Signalized Intersections. Urban Transport of China, 2010, 8(4):67-72.
Xuefeng Chen,Wanjing Ma. Simulation-based analysis of the dilemma zone of intersection under the coordinated control. Journal of transport science and engineer,2011,27（3）:87-93.
Wei Huang, Wanjing Ma, Xiaoguang Yang. Dilemma Zone-oriented Actuated Signal Control. Journal of Transport Information and Safety ,2009,18（04）:75-79.
Wei Huang, Xiangdong Jin, Wanjing Ma. Primary Research on dilemma zone signal control. Proceedings of 4th China annual conference on intelligent transport systems,2008:317-323.
Cunbao Zhang,Chao Chen,Xinping Yan. Methods for Alleviating Dilemma Zone Problem of Signal Control Intersection Based on Cooperated Vehicle Infrastructure System. China Safety Science Journal,2012,22（6）:86-91.
Hao Chu, Xiaoguang Yang, Tong Zhu, Zhuo Wang. Active Traffic Safety Technology in Intersection Based on Intelligent Vehicle-Infrastructure System. Computer and Communications,2008,26（4）：135-139.